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CHARGED WATER SPRAYS FOR DUST CONTROL IN HARD ROCK MINES

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CHARGED WATER SPRAYS FOR DUST CONTROL IN HARD ROCK MINES

by

G. Knight*

ABSTRACT

The staff of the Elliot Lake Laboratory tested charged water sprays in five sites in a hard rock mine. Four of these sites were underground. The dust control was found to be significant only when the airflow passing the spray heads was less than about 0.5 m^3/s. At airflows above 1.5 m^3/s past the spray heads the measured respirable dust removal was about 5 %. At the lowest airflows tested mist settling onto the obligatory safety glasses posed a safety hazard.

Some difficulties were realized in checking the operation of the charged sprays. Due to the difficulty of finding an effective ground return, most metal components in the gallery were not electrically grounded. The power supply conduit had a break in its ground continuity. Improved indicators are required for future tests to permit assurance connections are correct and that a charging current is flowing.

KEYWORDS: Dust control; Electrostatic charged sprays; Underground mine test.

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EMPLOI DE VAPORISATIONS CHARGEES POUR LUTTER CONTRE L'EMPOUSSIERAGE DES MINES EN ROCHE DURE

par

G. Knight*

Le personnel du Laboratoire d'Elliot Lake a fait l'essai de vaporisations d'eau chargées dans une mine en roche dure, à cinq emplacements. Quatre des emplacements étaient sous terre. La lutte contre l'empoussiérage n'a donné de bons résultats que quand le débit d'air passant sur les vaporisateurs était inférieur à environ 0,5 m^3/s. A débits supérieurs à 1,5 m^3/s, l'élimination mesurée des poussières inhalables était de 5 % environ. Aux débits les plus faibles, les lunettes de sécurités dont le port est obligatoire s'embuaient, ce qui était dangereux.

Certaines difficultés ont été constatées lors de la vérification du fonctionnement du système de vaporisation. En raison de la difficulté d'établir une mise à la masse efficace, la plupart des éléments métalliques de la galerie n'étaient pas à la masse électrique. La mise à la masse de la canalisation contenant le câblage d'alimentation n'était pas continue. Il faudra donc, pour les prochains essais, de meilleurs indicateurs permettant de vérifier que la mise à la masse est bien réalisée et qu'il passe bel et bien un courant de charge.

MOTS CLÉS: Lutte contre l'empoussièrage, vaporisations chargées électrostatiquement, essais en mine souterraine.

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INTRODUCTION

The use of charged water sprays has been suggested as a means of increasing mobility of dust particles and facilitating dust collection. The topic has been reviewed and excellent dust control demonstrated in a laboratory dust chamber (1). The main factors suggested as contributing to increased efficiency were water to air flow ratio and residence time. The underground test sites were chosen to represent possible applications with the longest residence times available in a hard rock mine extraction operation.

Parallel measurements results obtained in the final series of tests have been reported elsewhere (2,3). This paper outlines all of the results and compares them with the previous laboratory and theoretical results (1).

TEST SITES

The first site was an ore transport gallery on surface, while in many respects suitable, a preliminary examination showed that the gallery was not airtight and wind driven air leakage rendered the unsuitable for quantitative measurement. The second and third sites, chosen by G. Knight, were in ore transport and crushing operations underground where the ventilation and dust source layouts facilitate dust measurement in the airstream before and after the sprays. The fourth site was in an ore handling area near the shaft bottom: the air flows were indefinite and estimates of efficiency were not obtained.

The first underground test site was a 110 m long section of a 3.5 x 3 m gallery containing a main ore transport belt conveyor. The air velocity was about 1.8 m/s, and the residence time between the sprays and the final sampling station was about 45 seconds. The layout of the site and sampling stations is shown in Figure 1. The main sources of dust were the crusher, the loading station and the belt.

The second underground test site was a 66 m long by 4 x 3 m gallery. The airflow in the second set of tests was about - 0.3 m/s corresponding to a maximum residence time of 130 seconds. The dust source was the outlet from a bag filter in the crusher house which had a relatively high dust loading. This dusty air was mixed in the gallery with an approximately equal quantity of relatively clean air. Two brattice barriers were erected in the gallery to reduce the cross sectional area, increase the air velocity and thereby mix the

Legend

X - Sampling station
D - Dust sampler
R - Radiation sampler

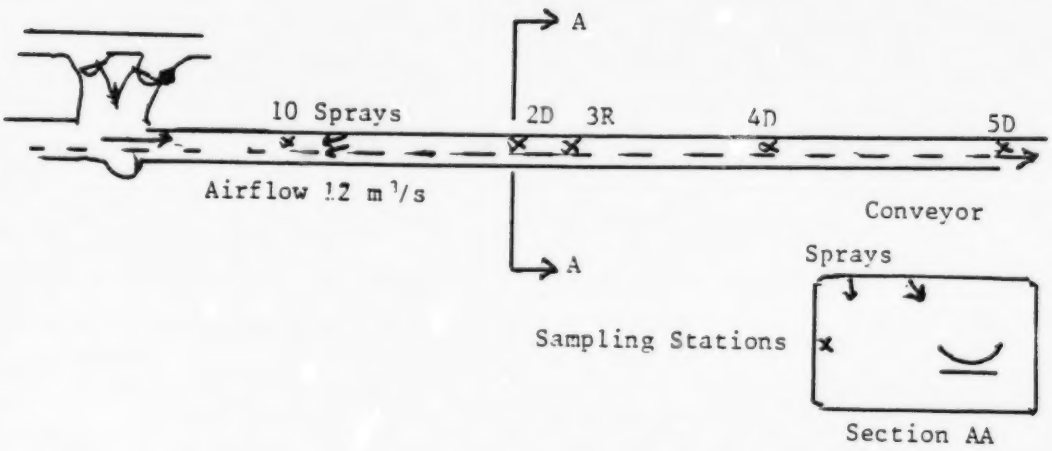

Fig. 1 - Test site 1 - conveyorway.

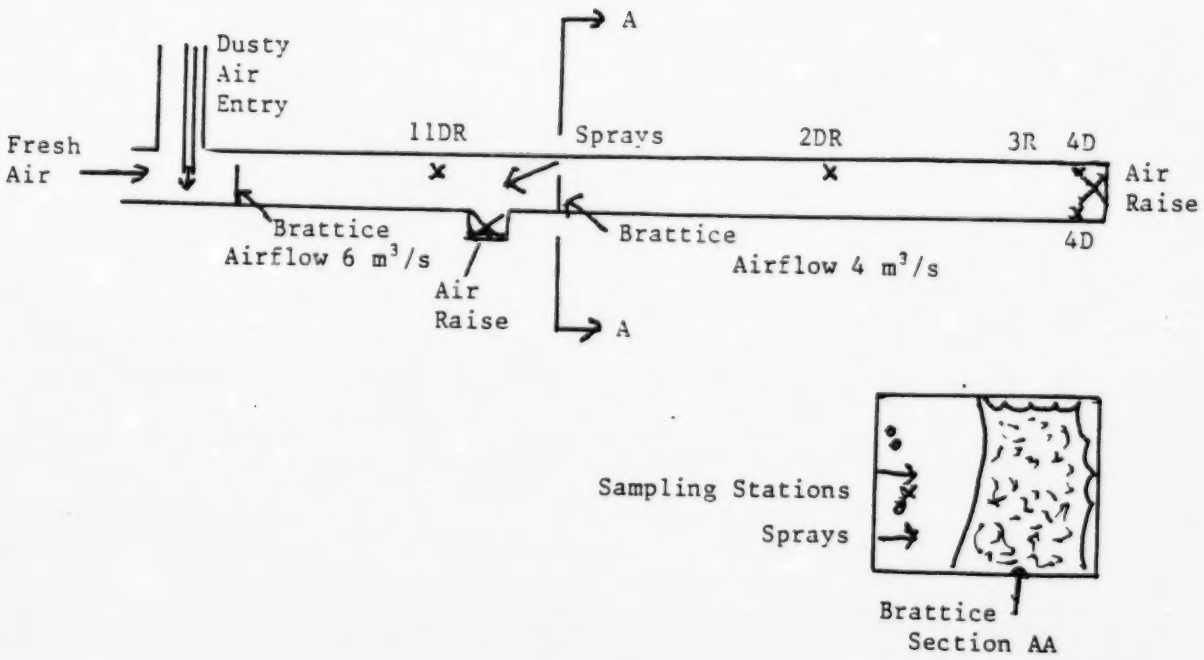

Fig. 2 - Test site 2 - crusher filter return gallery.

dust more uniformly in the air approaching the before and after spray sampling stations. The layout is shown in Figure 2.

The final set of tests was made at the second underground test site concurrently with measurements by others (2,3) using the before sampling station brattice too far down the heading to be useful in mixing the dust for the intake sampling stations. The airflow was lower than before and variable ranging from unmeasurable to 0.2 m/s. The residence times measured ranged up to 16 minutes.

CHARGED SPRAY GENERATORS

A pair of Dustron charged spray generators were used (4). Each one consisted of a compressed air atomizer with a charging field induced by a high voltage coil in an insulated enclosure. The air pressure to the atomizers was regulated to about 400 kPa (60 psi). The water flow was regulated to about 70 kPa (10 psi). The water flow was read on a taper tube flowmeter. The water flow was set to 1 US gal/hr (about 1 l/s) through each spray in most tests. The charging circuit included an indicator light showing that the 12 volt power supply, of either polarity, reached the spray head. Effective function of the charging circuit had to be determined by measurement of the spray current. This was accomplished by placing an insulated metal screen (1 mm mesh, 150 mm square) in the spray close to but not touching the spray head and discharging it to ground through a micro-ammeter. This measurement was easy in the laboratory but difficulties were found in the mine in finding a good electrical ground.

No spray current measurements were made in the first set of underground tests because the manufacturers instructions were not clearly received. One measurement was made in the second set of tests, where the result was 10 times less than expected at 0.5 μA. Subsequent tests in the laboratory showed the expected value of about 5 μA. In the final set of tests the expected spray current value of about 5 μA was found after trying a number of possible metal parts near the spray station as an electrical ground. The electrical conduit, used in the second set as a ground, was found not to be an adequate electrical ground, the only satisfactory ground located was the trolley return rail after cleaning.

It was presumed that the charging of the sprays functioned in the first 2 series of tests because the measurements indicated a small, but statistically

significant, difference between the tests with and without the charge on the spray.

MEASUREMENT TECHNIQUES

The main objective was to measure relative dust concentrations in the air body as it approached and as it left the spray section. These tests were carried out under three conditions: (1) charged spray, i.e. normal operation; (2) water sprays uncharged-control status one; and (3) no sprays-control status two. Systematic errors could arise due to differences between the individual samplers; to dust production in the test section and to dust losses in the test section arising from mechanisms other than the effect of the charged spray. These systematic errors were grouped together by using the individual instruments in the same place in each series of tests. The control tests were intended to ascertain the systematic errors and enable correction.

The main dust samplers used were the new 4 litre/minute samplers recently developed by the Elliot Lake laboratory (5). The respirable dust filters were assessed by gravimetry and X-ray diffraction for quartz (6-8). These gave 5 measurements for each filter. Replicate samplers were used before and after the spray section. In addition a new 30 litre/minute size selective sampler was tested (5). With this, gravimetric assessments of coarse and respirable dust were made. The results give the weights of total (coarse plus respirable) dust and respirable dust. The respirable dust filter was also assessed by alpha counting for radon daughters, thoron daughters and long-lived radionuclides.

RESULTS

Detailed results are given in the appendix to the internal report (9). These results for the three conditions; charged sprays, water only sprays and no sprays. It can be seen that the effect, if any, is small and that only the replicate respirable dust samplers showed a statistically significant effect of about 5 % in dust removal. A larger effect, about 30 %, was found in the third series of tests when the air flow was lower as might be expected. There were insufficient control tests conducted to determine the dust losses and systematic errors.

Detailed parallel results taken in the final series of tests have been given elsewhere (2,3). The differences between the sets of measurements by the two groups were small and probably explained by the choice of intake sampling stations. Neither of the stations chosen could be expected to be entirely satisfactory.

DISCUSSION

The discussion on the laboratory tests of charged sprays (1) suggested that water to air flow ratios greater than 20 (in ml/m^3) would be optimal. The lowest ratio tested in the laboratory was 4. In the in-mine tests the highest ratio achieved with 2 charged sprays was 4. At ratios above 1, safety hazards arose because of reduced visibility mainly due to deposition of mist onto the obligatory safety glasses. To achieve the recommended water/air ratio in most underground ventilation airflows would require many charged spray units. The 2 tests in which the water flow rate through each spray was doubled showed an apparent increase in dust collection efficiency, but the difference was not statistically significant.

The mine tests, at the highest water/air ratios, indicated dust removal efficiencies within the range of the laboratory results (Fig. 29, Reference 1). The expected exponential decay effect of residence time was not observed in the results obtained at various distances downwind of the spray position. But the results were not sufficient to really pick it out from the experimental errors. It was not apparent how to use the equation (on page 101) and Figure 29, from Reference (1) to check our other results because the results were obtained below the limit of the experimental determination of the decay rate, R_D. The extrapolation required could be linear or strongly curved as suggested in Figure 29.

It appears that the use of charged sprays in the extraction area of the mine is not likely to be an effective dust control measure because of the introduction of substantial safety (visibility) and noise hazards. There may be some areas where this might be considered as a possible dust control expedient, particularly if the process is enclosed or only inspected occasionally.

There are two major uncertainties in the final set of tests as follows; Firstly, the mixing of the approximately equal quantities of comparatively dirty

Table 1 — Summary of penetrations and collection efficiencies of charged sprays

	Penetrations - fractional			Collection Efficiency %	Statistical Significance t test
	No Sprays MR[1](n)[2]S.D.[3]	Uncharged MR(n)S.D.	Charged MR(n)S.D.		
Coarse dust by mass					
Test 1,2 4l/min	0.93(3)0.16	0.94(3)0.45	0.87(7)0.19	6	–
30l/min	0.56(2)0.26	0.42(1) -	0.66(5)0.045	–	–
Test 3 30l/min	–	1.00(1) -	0.70(4)0.11	30	–
Respirable dust by mass					
Test 1,2 4l/min	1.08(10)0.24	1.18(6)0.19	0.96(14)0.05	11	0.05
30l/min	0.95(1)	0.90(1) -	0.84(4)0.08	11	–
Test 3 4l/min	1.03(4)0.12	0.98(8)0.13	0.73(16)0.045	25	0.001
30l/min	–	0.75(1) -	0.82(4)0.16	–	–
Respirable quartz by mass					
Test 1,2 4l/min	0.99(40)0.08	0.97(24)0.13	0.92(56)0.05	5	0.01
Separated by site					
Site 1	0.97	0.96	0.92	4	–
Site 2	1.01	0.99	0.92	7	–
Test 3 4l/min	0.85(16)0.11	1.04(32)0.12	0.78(64)0.08	32	0.001

Footnotes

1 - MR mean ratio after/before measurements

2 - n number of measurements

3 - S.D. standard deviation of an individual measurement

and clean air and secondly, determining the airflow. Because of the shortness of the second test gallery and the difficulty of erecting airflow mixing barriers with good seals to the walls, the air streams were not well mixed and a single intake sample could not be expected to be representative of the entire airflow cross-section. This is believed to be the major uncertainty in the calculated dust collection Figures. There were insufficient samplers available to cover the entire cross-section. Secondly, with measured air velocities ranging from not detectable to 0.2 m/s during the course of one test it is difficult both to achieve representative samples and to estimate an appropriate air flow to describe the experiment.

There were difficulties in determining the correct functioning of the charged sprays. These arose from three major causes as follows:

1. The power-on indicator lights on the spray heads illuminated even when the power supply was wrongly polarized. It was found possible to misconnect the supposedly polarized electrical plugs and sockets.
2. There is no indicator for spray current flow operation. The manual testing technique while using simple equipment is difficult and time consuming to use in the mine.
3. It was difficult to find and maintain a good electrical ground for the measurement of spray current. This was found desirable on each test day.
4. On one day out of six the sprays were found to be non-functional. Cleaning to the manufacturers recommendations restored the function as indicated by the current flow test was required.
5. Charging current were only checked at the beginning of each test. It would have been desirable to check the current during the test.

ACKNOWLEDGEMENTS

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APPENDIX - Detailed Results

This appendix gives the detailed results obtained by the author only. The results obtained by Grenier and Frattini are given in their published papers (References 2 and 3 in main text).

Table 1 shows the dust measurements obtained in the first and second series of tests at the intake sampling station. These are expressed as weights of dust on the filter, which is all that is needed for determination of efficiency. The precision of results depends more on the weight of dust collected than on the concentration. All samplers were run for the same length of time, usually longer than the period of dust generation. Table 2 shows the corresponding measurements obtained at the sampling stations after the sprays.

Table 3 shows the calculated penetrations for each test in the first 2 series. These are given as (mean of after concentrations)/(mean of before).

Tables 4, 5 and 6 show similarly the results for the final series of tests.

Table 1 - Results before sprays - Station 1.

Site	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
Water flow both sprays mL/sec	0	0	0	2	2	2	2	0	0	2	1	2	2	4	4
Charge	-	-	-	-	-	Yes	Yes	-	-	-	Yes	Yes	Yes	Yes	Yes
Run No.	2	5	7	1	6	3	4	9	11	12	13	8	10	14	15
Sampling time/min	145	220	257	146	91	273	218	62	106	188	72	149	75	78	103
Operating time/min	106	192	157	140	86	241	218	52	100	105	63	135	71	72	94
Air velocity m/sec	1.8	1.8	1.8	1.8	1.8	1.8	1.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
4 L/min sampler #1															
Coarse dust ug	-	20	200	300	20	490	480	780	1550	1450	1150	1190	590	1040	1150
Respirable dust ug	340	260	370	180	120	450	-	570	1360	950	820	1160	690	790	660
Respirable quartz 100 *	101	96	123	88	45	165	218	328	882	691	592	721	396	534	431
101 *	106	104	135	80	49	183	200	355	1048	727	627	753	508	542	457
112 *	101	118	123	92	43	179	199	328	983	737	637	798	468	528	493
211 *	93	133	111	61	47	160	194	332	845	669	590	738	413	511	399
#2															
Coarse Dust ug	-	110	450	-	420	190	420	560	1330	260	1010	1130	750	1210	1320
Respirable dust ug	-	280	360	-	100	480	530	580	1360	930	760	1150	600	740	760
Respirable quartz 100 *	-	99	147	-	50	208	205	317	847	637	551	713	377	451	491
101 *	-	118	155	-	43	196	191	344	1032	721	597	747	387	464	523
112 *	-	127	140	-	41	221	200	368	948	707	600	792	410	457	538
211 *	-	110	131	-	48	189	203	309	829	625	547	751	349	420	472
30 L/min samples															
Coarse dust ug	-	-	-	-	-	-	-	6300	16400	15000	12700	12400	7300	10700	11800
Respirable dust ug	-	-	-	-	-	-	-	6050	9740	7240	6000	-	4430	5040	5120

Note: * the quartz was measured on four diffraction lines in μg.

Table 2 - Results after sprays

Run No.	2	5	7	1	6	3	4	9	11	12	13	8	10	14	15
4 L/min sampler No. 1															
Residence time/sec	11	11	11	11	11	11	11	65	65	65	65	65	65	65	65
Coarse dust µg	360	40	180	120	40	300	480	430	570	610	560	350	380	440	690
Respirable dust µg	380	260	350	180	100	450	-	520	1290	840	670	770	540	590	550
Respirable quartz 100*	94	146	130	67	46	156	197	291	753	602	487	489	299	329	333
101	108	102	131	72	60	177	172	317	936	675	507	473	399	373	350
112	115	136	124	70	44	200	184	307	880	609	471	508	332	362	372
211	107	115	130	75	49	168	182	283	772	579	442	437	321	340	309
No. 2															
Residence time/sec	28	28	28	28	28	28	28	130	130	130	130	130	130	130	130
Coarse dust µg	-	420	160	240	110	170	490	670	1370	1410	1180	990	590	780	1090
Respirable dust µg	610	260	250	200	270	450	490	580	1460	910	820	1030	640	650	790
Respirable quartz 100*	131	91	121	80	35	180	190	322	878	675	582	691	407	367	428
101	96	92	110	74	42	180	166	315	1059	702	626	679	478	421	493
112	99	91	85	66	35	190	227	326	1022	709	606	738	414	408	497
211	99	85	96	74	37	147	188	287	894	628	530	645	386	382	481
No. 3															
Residence time/sec	43	43	43	43	43	43	43	130	130	130	130	130	130	130	130
Coarse dust µg	-	160	380	490	160	100	450	650	1650	970	1300	1250	540	660	1020
Respirable dust µg	-	280	400	210	80	-	490	590	1260	1060	760	1100	630	720	690
Respirable quartz 100*	-	98	123	66	48	190	193	339	909	725	496	698	375	425	405
101	-	107	137	81	51	167	172	350	1067	725	536	716	470	445	426
112	-	122	132	73	63	178	169	385	991	725	532	708	445	482	445
211	-	121	107	68	40	151	178	314	860	644	448	709	359	425	381
30 L/min sampler															
Residence time/sec	-	-	-	-	-	-	-	65	65	65	65	65	65	65	65
Coarse dust µg	-	-	-	-	-	-	-	2400	2400	6300	8100	9000	4600	6600	8300
Respirable dust µg	-	-	-	-	-	-	-	-	9200	6540	5510	-	3950	3820	3990

Note: * the quartz was measured on four diffraction lines.

Table 3 - Penetrations through test section (uncorrected measurements, i.e., including systematic errors).

Site		1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
Water flow mL/sec both sprays		0	0	0	2	2	2	2	0	0	2	1	2	2	4	4
Charge *		-	-	-	-	-	Yes	Yes	-	-	-	Yes	Yes	Yes	Yes	Yes
Run No.		2	5	8	1	6	3	4	9	11	12	13	8	10	14	15
Air flow m^3/sec		19	19	19	19	19	19	19	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
		Penetrations after mass/before mass														
4 L/min sampler																
Coarse Dust		-	-	0.75	0.93	0.50	0.63	I.04	0.99	1.05	1.39	1.14	0.96	0.84	0.64	0.85
Respirable dust		1.50	1.00	0.88	1.09	1.40	0.97	0.92	1.01	1.06	1.05	1.00	0.92	0.99	0.90	1.04
Respirable quartz	100	1.11	1.15	0.92	0.81	0.91	0.93	0.92	1.02	1.03	1.05	0.94	0.97	1.01	0.81	0.90
	101	0.96	0.90	0.88	0.93	1.11	0.92	0.87	0.95	1.02	0.99	0.93	0.93	0.97	0.86	0.94
	112	1.06	0.95	0.98	0.76	1.12	0.92	0.97	1.02	1.04	1.00	0.92	0.91	0.98	0.90	0.91
	211	1.11	0.88	0.88	1.18	0.88	0.89	0.92	0.94	1.03	0.93	0.78	0.91	0.98	0.87	0.99
30 L/min sampler																
Coarse dust									0.38	0.75	0.42	0.64	0.72	0.63	0.62	0.70
Respirable dust									-	0.95	0.90	0.92	-	0.89	0.76	0.78

Table 4—Results of Test 3; Measurements before sprays

Site	2	2	2	2	2	2	2
Water flow both sprays ml/s	0	2	2	2	2	2	2
Charge	-	-	-	yes	yes	yes	yes
Run number	19	18	22	16	17	20	21
Sampling time minutes	135	165	140	30	116	90	157
Crusher operating time minutes	120	130	129	19	98	78	147
Air velocity m/s	0.1	0.1	0.15	0.1	0 to 0.2	0.03-.06	0.1
4 l/min sampler # 1							
Respirable dust μg	1670	1900	1750	380	1250	1380	1000
Respirable quartz μg 100	916	1005	847	217	709	569	658
101	920	963	829	265	712	561	663
112	1044	1136	931	258	788	543	651
211	923	869	760	256	757	579	665
4 l/min sampler # 2							
Respirable dust μg	1570	1870	1260	440	1520	990	1170
Respirable quartz μg 100	879	1050	765	272	858	619	768
101	920	939	715	286	836	586	750
112	1009	1116	778	285	961	627	802
211	915	969	702	288	833	552	740
4 l/min sampler # 3							
Respirable dust μg	1770	1940	1240	380	1260	1390	1330
Respirable quartz μg 100	783	1055	693	261	683	795	742
101	818	960	679	267	696	827	728
112	934	1127	678	268	756	900	747
211	827	986	674	293	720	779	699
4 l/min sampler # 4							
Respirable dust μg	1650	1780	1280	420	1480	1180	1280
Respirable quartz μg 100	799	941	707	276	728	801	855
101	767	942	683	270	930	750	785
112	867	1093	740	279	1017	755	876
211	755	957	628	280	856	739	795
30 l/min sampler							
Total dust μg	-	-	25670	6960	20130	16450	17330
Respirable dust μg	-	-	9070	2960	10130	5750	7230
Radon daughters counts/s	-	-	ND	81	100	33	58
Thoron daughters counts/s	-	-	500	87	283	65	130
Long lived radionucleides c/s	-	-	-	1.1	3.8	1.5	-

Table 5—Results of Test 3; Measurements after sprays

Site	2	2	2	2	2	2	2
Run number	19	18	22	16	17	20	21
4 l/min sampler # 1							
Respirable dust μg	1440	2080	1250	350	1170	820	840
Respirable quartz μg 100	768	1072	668	208	636	521	555
101	743	1028	607	196	584	503	536
112	834	1155	711	187	618	521	604
211	735	1050	670	165	561	456	527
4 l/min sampler # 2							
Respirable dust μg	1530	2090	1270	210	1220	1060	870
Respirable quartz μm 100	794	1041	677	97	703	407	558
101	737	1004	631	115	675	517	568
112	820	1140	711	90	743	561	610
211	734	971	630	86	680	483	598
4 l/min sampler # 3							
Respirable dust μg	1430	2210	1210	230	1180	840	940
Respirable quartz μg 100	722	1259	660	151	736	520	614
101	687	1227	645	176	686	522	573
112	771	1520	755	166	756	518	600
211	689	1414	707	143	727	497	612
4 l/min sampler # 4							
Respirable dust μg	1440	1950	1110	380	1200	840	890
Respirable quartz μg 100	722	1150	634	206	597	396	621
101	715	1137	633	212	577	408	580
112	812	1350	713	183	666	442	648
211	687	1232	658	186	612	381	612
30 l/min sampler							
Total dust μg	–	–	28470	3800	15270	12900	11650
Respirable dust μg	–	–	6770	2300	7570	6100	5650
Radon daughters counts/s	–	–	ND	60	110	60	150
Thoron daughters counts/s	–	–	580	75	233	87	180
Long lived radionucleides c/s	–	–	–	0.9	2.2	1.7	–

Table 6—Penetration through test section in final series of tests

Site	2	2	2	2	2	2	2
Water flow both sprays ml/s	0	2	2	2	2	2	2
Charge	-	–	–	yes	yes	yes	yes
Run number	19	18	22	16	17	20	21
Sampling time minutes	135	165	140	30	116	90	157
Crusher operating time minutes	120	130	129	19	98	78	147
Air velocity m/s	0.1	0.1	0.15	0.1	0-0.2	0.03-.06	0.1
	Fractional penetration (conc. after)/(conc. before)						
4 l/min samplers							
Respirable dust μg	0.88	1.11	0.85	0.67	0.78	0.72	0.74
Respirable quartz μg	0.85	1.09	0.98	0.58	0.82	0.65	0.84
30 l/min sampler							
Total dust μg	–	–	1.00	0.55	0.78	0.78	0.67
Respirable dust μg	–	–	0.75	0.71	0.75	1.06	0.78
Radon daughters counts/s	–	–	ND	0.74	0.91	1.80	2.00
Thoron daughters counts/s	–	–	1.16	0.81	0.82	1.33	1.20
Long lived radionucleides c/s	–	–	–	0.82	0.58	1.13	–